1.5 The Immune System

During medieval times in Europe, people worked very hard to farm and to tend their agricultural lands to produce enough food for their survival. Land was so valuable that wars often erupted over good farmland. Invading armies would attempt to take the land that people worked so hard to tend, so great fortresses were built for protection. If an army invaded, people from the surrounding countryside could move inside the castle to be protected by the thick castle walls. Any damage to the walls would quickly be patched by stonemasons. The castle could only be entered through guarded gates and across moats that could drown enemies.

Castle guards were posted along the walls to spot invaders, while other sentries patrolled and attacked any invaders who managed to sneak in. Different invading armies would use unique approaches and techniques to try to get into castles. After repelling the attack of an invading army, the defenders would be better able to respond to the same enemy if they tried to invade again.

Think of your body as if it were a medieval fortress. Different parts of your body act to maintain an ideal environment for the growth, health, and functioning of your cells. The organs in your body constantly work to provide the cells with a continuous supply of nutrients and to create a comfortable temperature and chemical environment. Unfortunately, the internal environment that the body works hard to create and maintain is also an ideal environment for the growth of disease-causing agents. These substances, often called germs or **pathogens**, are microscopic and act like foreign armies because they are constantly trying to invade the fortress of the human body.

pathogen: an agent, especially a virus or a bacterium, that causes disease

The human body has many ways to defend itself from pathogens:

- The skin covering the human body is a protective barrier, and it acts like the thick stone walls of a fortress. Skin is the first line of defence and prevents most disease organisms from getting inside the body.
- Because the sweat and oil secretions produced by the skin are acidic, bacterial growth is minimized.
- In Lesson 1.4 you learned about the role of platelets. These disks quickly create clots to repair damaged or broken skin to keep out foreign organisms. In a similar way, stonemasons repair damaged castle walls with replacement stones and mortar.
- The body has barriers that help defend these openings. For example, the nasal passage has hairs that work as filters, and mucous secretions trap most disease-causing organisms before they can reach the lungs. As well, the eyes are protected by an antiseptic liquid in your tears, and the stomach contains strong acid that kills most swallowed germs.
- The human body even has a defending army of white blood cells that act like soldiers—white blood cells attack pathogens that manage to break through the first line of defence to invade the body.

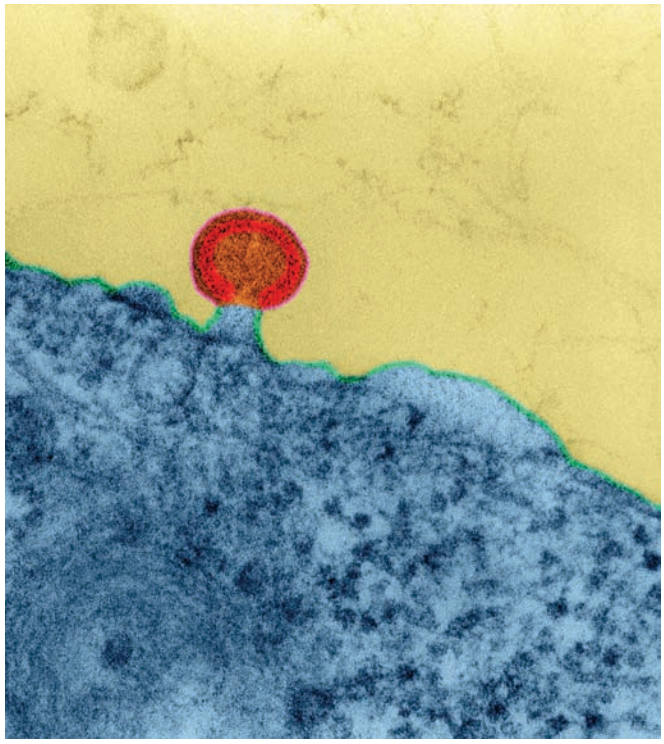


Figure A1.16: An HIV virus particle penetrates a cell membrane of human lymph tissue.

Practice

45. After reading the lesson introduction, copy and complete the following table that compares the roles and parts of a castle fortress to the parts of the immune system.

Part of Immune System	Role	Part of a Castle
		castle walls
cilia and mucous secretions		
	patch holes in protective barrier	
white blood cells		

Spreading Disease

If the body's natural defenses are not able to destroy or block a pathogen from entering it, the pathogen will begin to reproduce and spread. Even in the most sanitary living conditions, people regularly encounter microscopic substances that can get into their bodies, reproduce, and make them feel sick. These invading germ organisms can be passed along in several ways. When someone sneezes, coughs, or even talks, tiny droplets are expelled from the lungs. If this person's body has been infected by a disease-causing organism, like the influenza virus—which causes what is commonly referred to as the "flu"—or tuberculosis (TB), these expelled droplets will contain some of the pathogens. When other people breathe in these droplets, they can become infected by the pathogen.

DID YOU KNOW?

In some cases, bacteria and viruses can survive for months on the surfaces of everyday objects. When you touch an object, like the handle on an escalator in a shopping mall, you can transfer these pathogens to your hands and from there to your eyes, nose, or mouth, allowing pathogens to enter the body.

Regularly washing your hands is one of the best ways to avoid getting sick. All you need is soap and water. Ideally, you should rub your hands together for at least 15 s and scrub all surfaces including your wrists, under your fingernails, between your fingers, and the backs of your hands.

Food Poisoning

Pathogens can enter the body through the digestive system if contaminated food or water is ingested. The acid environment of the stomach is normally able to kill disease organisms. Food poisoning—an intense disturbance of the digestive tract—occurs when food is not cooked thoroughly, is improperly stored, or when the food is prepared in unsanitary conditions. For example, one type of food poisoning is caused by eating food contaminated with salmonella bacteria. Other instances of food poisoning can be seen in the "Common Types of Bacterial Food Poisoning" table.

Cholera is a disease caused by a type of bacteria often found in dirty and untreated water. If the cholera bacteria are not killed by the low stomach pH, the bacteria can multiply in the intestine and infect the blood supply or release toxins that harm the body.

COMMON TYPES OF BACTERIAL FOOD POISONING

Bacterium	Habitat	Common Food Sources	Symptoms
salmonella	animal and human intestinal tracts	high protein foods like meat, poultry, fish, and eggs	diarrhea, vomiting, nausea, chills, and fever within 12 to 24 hours
clostridium botulinum (botulism)	soils, plants, marine sediments, and fish	improperly canned foods	blurred vision, respiratory distress, and possible death
listeria monocytogenes	soil, vegetation, and water—can survive for long periods in soil and plant materials	milk, soft cheeses, vegetables fertilized with manure	flu-like symptoms that mimic meningitis—elderly and babies most susceptible
E. coli (travellers' diarrhea)	feces of infected humans	meat and cheeses	diarrhea, abdominal cramps, no fever

Pathogens in the Bloodstream

HIV and the virus causing hepatitis C are examples of viruses transmitted through the bloodstream. When the skin is punctured or cut, pathogens can enter the bloodstream before platelets can seal up the breach. Cuts should be washed out and then covered with sterile bandages and dressings.

DID YOU KNOW?

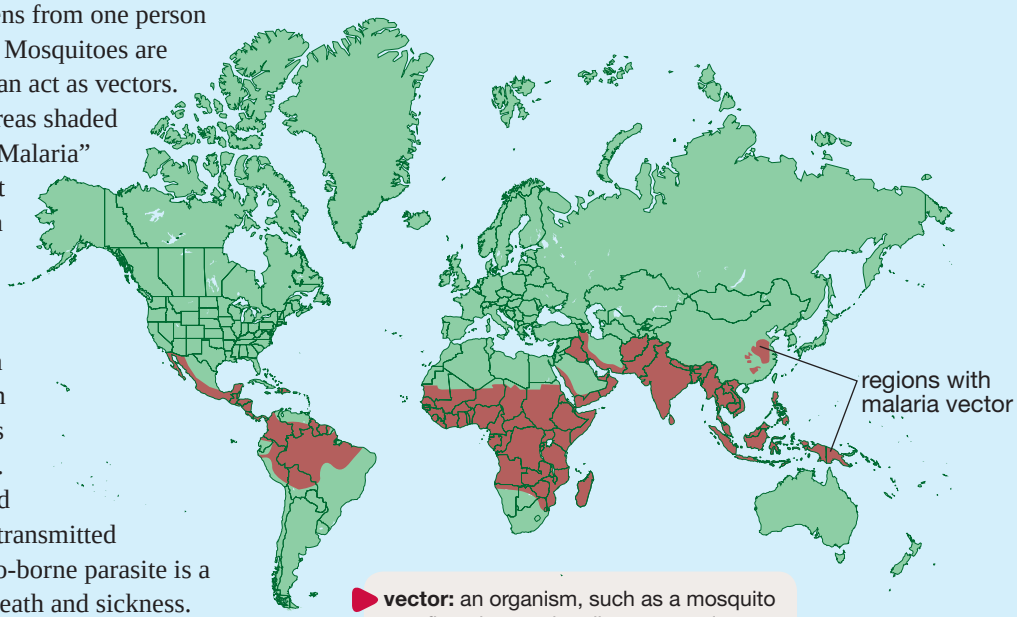
During the 1300s, an outbreak of the bubonic plague, or Black Death, occurred in Europe. This disease was carried by the fleas that initially lived on rats. After the rats died, the fleas passed the disease on to humans. In just five years, the Black Death killed about 25 million people, or the equivalent of one-quarter of Europe's population at that time.

There are still scattered cases of bubonic plague as the disease is often passed by flea bites from infected wild rodents—such as ground squirrels—to humans. If detected early, the disease is curable with modern medicines.

Vectors

Organisms that carry pathogens from one person to another are called **vectors**. Mosquitoes are examples of organisms that can act as vectors. In hot climates, such as the areas shaded brown on the "Prevalance of Malaria" map, mosquitoes can transmit the potentially deadly malaria parasite. When a mosquito punctures the skin to draw blood, it pumps some of its saliva into the bite. The saliva contains a chemical, called an anticoagulant, which prevents clotting while blood is drawn. The malaria parasite is carried in the mosquito saliva and is transmitted during the bite. This mosquito-borne parasite is a leading worldwide cause of death and sickness.

Prevalance of Malaria



vector: an organism, such as a mosquito or a flea, that carries disease-causing pathogens from one person to another

Try This Activity

Preventing Infection Poster

Design a poster that could be used to educate primary school students (grades 1 to 3) about the importance of good hygiene and practices that can help prevent infection by disease-causing pathogens. The poster should be colourful and attractive enough to appeal to young students.

Alternatively, your teacher could arrange for you to make a presentation to a primary school class on this topic or invite a primary school class to choose their favourite poster.

Joseph Lister (1827–1912)

During the nineteenth century, people who survived a successful medical operation often died due to infections that occurred during the operation. Most often, the infected wounds developed into gangrene or sepsis. Gangrene usually occurs in the extremities when cell tissues die because circulation has been lost in that area. A bacterial infection can cause a loss of circulation and result in gangrene. Sepsis is an illness that develops from a bloodstream infection by toxin-producing bacteria. At the time, there was not a complete understanding of how disease-causing agents were transmitted.

Joseph Lister was a British surgeon who studied Louis Pasteur's work on micro-organisms. Lister believed that hospitals needed to be clean and that he needed to kill unseen micro-organisms that were getting into wounds from the air. He began spraying a solution of carbolic acid onto wounds during operations and soaking dressings used for bandaging wounds in carbolic acid. This practice prevented the wounds from becoming septic. Lister's work with **antiseptics** reduced post-operation infections and saved many lives.

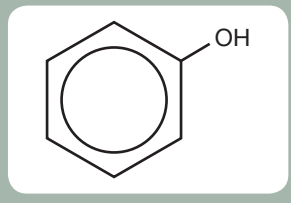
antiseptic: a solution or substance that prevents or inhibits the growth of micro-organisms

DID YOU KNOW?

The mouthwash called Listerine was developed in the late 1800s for use as an antiseptic for surgical procedures. Its inventors named the product after Joseph Lister, who pioneered antiseptic surgical procedures. It was soon discovered that the antiseptic solution was effective at killing mouth bacteria that cause bad breath and tooth decay. Listerine became popular and, in 1914, one of the first prescription drugs to be available over the counter.

Science Links

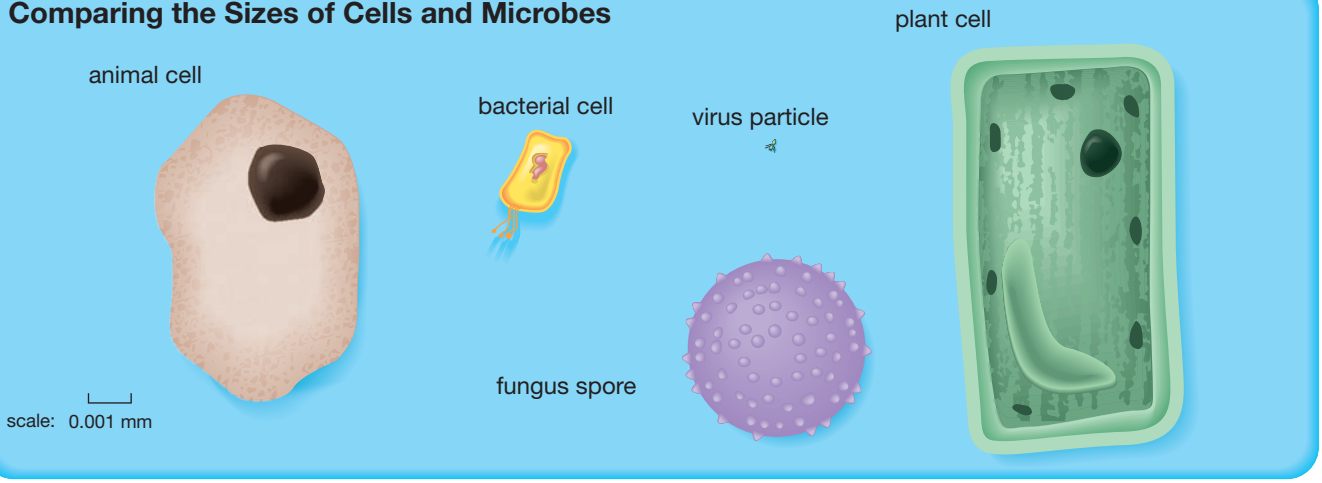
Carbolic acid is called *phenol* under the modern-day chemical naming system. Phenols are actually a group of compounds containing a ring of carbon atoms and an attached alcohol group. You will learn more about these chemical structures in Unit B. Phenols are still used as a component of commercial antiseptics.



Comparing Microscopic Pathogens

Micro-organisms live unseen all around. They are in the food and water that people ingest and in the air that they breathe. Most micro-organisms are harmless or even beneficial, such as those that live in your large intestine and play a role in digestion. If certain species infect a body or grow to large numbers, their negative effects cause the symptoms of disease.

Comparing the Sizes of Cells and Microbes



Protozoans

Malaria is caused by single-celled organisms called **protozoans**. Some protozoans live as parasites and require a host in which to reproduce. Because these protozoa exist with human cells, they are difficult to destroy without harming the host's cells. The protozoans that cause malaria are transmitted by a mosquito vector and infect human red blood cells.

protozoan: a group of microscopic, single-celled organisms that each have a nucleus

Many disease-causing protozoans can only divide within a host organism.

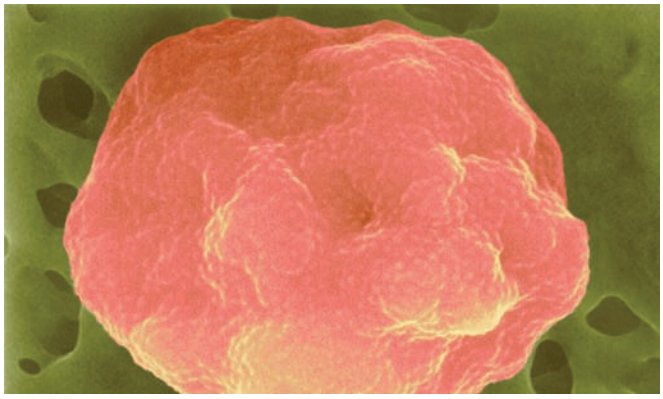


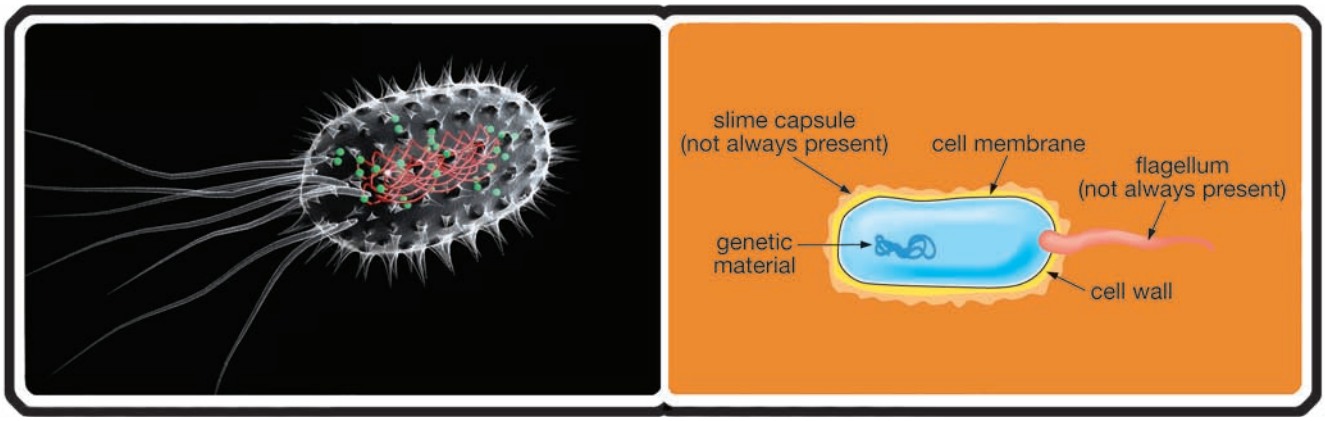
Figure A1.17: A red blood cell is infected with a malaria parasite.

Fungi

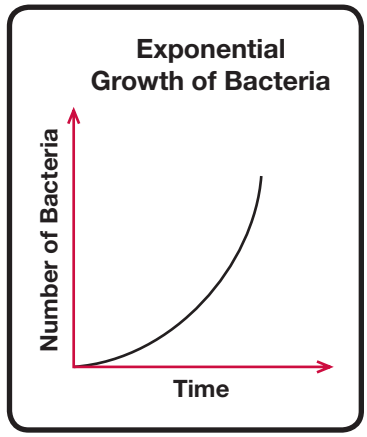
Mold, mushrooms, and yeast are all examples of **fungi**. Most fungi live off the remains of dead or decaying organisms, but some are parasitic. Athlete's foot is an example of a fungal infection.

fungi: organisms that absorb food in solution directly through their cell walls and do not conduct photosynthesis; reproduction occurs through spores

Bacteria



Bacteria are small, single-celled organisms with a cell wall and cytoplasm. Unlike plant or animal cells, their genetic material is floating in cytoplasm and is not contained in a nucleus. Bacteria come in many different sizes and shapes including spiral-shaped, rod-shaped, or round. Some bacteria have a long whip-like tail—called a flagellum—or several flagella to help them move. Bacteria reproduce rapidly by simply splitting in two and can grow exponentially under ideal conditions. As disease-causing bacteria grow inside of you, their life processes damage your cells or they produce toxins that make you feel ill. **Antibiotics**, such as penicillin, are drugs that kill bacteria and, therefore, can be used to reduce or stop bacterial infections.



bacteria: microscopic, single-celled organisms that lack a membrane-bound nucleus and membrane-bound organelles; reproduction is chiefly by cell division to produce identical daughter cells

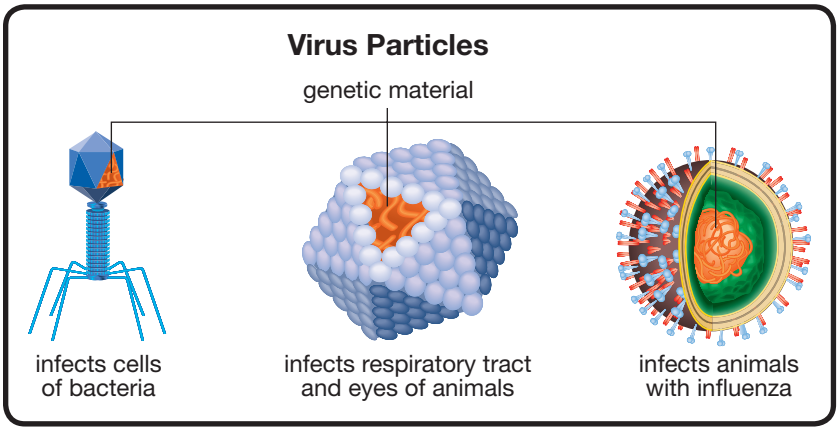
antibiotic: a drug that fights bacterial infections

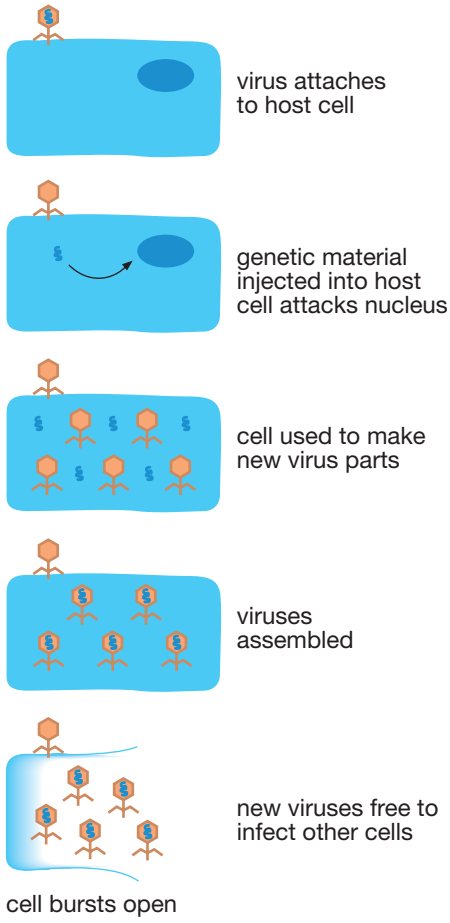
Viruses

Viruses are extremely tiny particles ($\frac{1}{100\text{th}}$ the size of a bacterium). Viruses do not grow, feed, or respire, so they are not considered to be cells. Scientists do not even consider them to be living organisms. They consist of a geometrically shaped protein coat and genetic material. Many viruses cause diseases. Viruses reproduce by infecting a host cell and injecting their genetic material into it, turning the host cell into a virus-making factory. Once new viruses are produced, the host cell ruptures and releases virus particles to infect more host cells. **Antiviral drugs** attempt to stop the infection of cells by viruses. These drugs also affect the development of new virus particles in the host cell.

Bacteria and viruses are the most common types of disease-causing agents that can make people feel sick. The illness symptoms are due to tissue damage caused by these disease agents and by how bodies respond to this tissue damage.

- **virus:** a non-cellular particle consisting of a protein coat surrounding genetic material that multiplies only within the cells of a living organism
- **antiviral drug:** a type of medication that controls or cures an infection from a virus





Practice

46. Record and complete the following table in your notes.

MICROSCOPIC PATHOGENS

Type of Pathogen	Defining Characteristics	Example of a Disease Caused by This Type of Pathogen
protozoans		
fungi		
bacteria		
viruses		

47. In the late 1800s, scientists were struggling in their early attempts to isolate and identify viruses. Attempts to filter the particles responsible for viruses from infected plant fluids were unsuccessful, as were attempts to observe these particles in standard light microscopes. Identify the property of viruses that would account for these early difficulties.

Utilizing Technology

Informing the Public About an Infectious Disease

Purpose

You and your partners will develop a concise bulletin to inform the general public about an infectious disease. Your bulletin could take the form of a brochure, a poster, a multimedia presentation, or some other presentation to your class.

Science Skills

- ✓ Initiating and Planning
- ✓ Performing and Recording
- ✓ Analyzing and Interpreting
- ✓ Communication and Teamwork

Background Information

You have been employed by a public health clinic to produce an informative bulletin about an infectious disease. Health-care professionals wish to use the brochure you create to help patients become more informed about diseases. Your teacher may assign you a disease topic or you may choose a topic. Remember that your bulletin must be about an infectious disease like meningitis, strep throat, SARS, chicken pox, or hantavirus, and not about hereditary or environmental diseases and disorders like cancer, Down syndrome, or atherosclerosis. Check with your teacher before beginning if you are unsure about your chosen topic.

Materials

You will need to assemble the materials necessary for the bulletin format that your group plans to develop. You will also need access to the Internet, school library, and other resources to research your topic and to produce a product that summarizes the information in your own words.

Procedure

Read through the entire procedure. Then decide how you will divide up the tasks among group members.

step 1: The first task for your group is research. You may use the Internet and/or other resources to determine answers to the following questions:

- What background information should the public know about the disease you have chosen?
- What are the signs and symptoms of the disease?
- How is this disease transmitted?
- How can the disease be prevented and/or treated?
- Who is at risk for getting this disease?
- What do current statistics reveal about the number of people infected?

step 2: Plan how you can clearly communicate the answers to the questions in step 1 by using the format you have chosen. Your bulletin should be concise and effective.

step 3: Carry out the plan you devised in step 2 by preparing your bulletin about the disease you chose.

step 4: Share your bulletin with other students.

step 5: View the bulletins of other students.

Evaluation

1. Ask your classmates for feedback on the bulletin your group produced. How effectively did your group's bulletin address the six key questions from step 1? What aspects of your bulletin could be improved?
2. What did you learn from the bulletins prepared by other groups? If you completed this activity again, what would you do differently?

Immune Response

The immune system is like an internal army that fights off disease-causing organisms able to invade the body's first lines of defence.

The descriptions that follow match the graphic titled "Overview of Immune Response."

(1) The first event that initiates the process occurs when an invading pathogen breaks through the body's protective layer of skin and enters body tissues or the bloodstream. Fighting an infection begins with the detection of the disease-causing organism. Your internal army is composed of white blood cells that constantly check the identity of every substance encountered in the bloodstream to distinguish between the parts of your body and potentially harmful foreign parts. Each organism or virus displays unique chemical structures—usually proteins—on its surface. These structures are called **antigens**. Antigens on the outer surface of pathogens act like fingerprints to allow cells of the immune system to recognize these substances as potentially harmful foreign pathogens and to eliminate them from the body.

(2) It is the job of a type of white blood cell called a **macrophage** (literally meaning big eater) to patrol the bloodstream and eat dead cells, cellular debris, foreign cells, and molecules from outside the body. When a macrophage engulfs and destroys a disease-causing agent, it does not destroy the foreign antigen.

(3) Instead, it presents the invader's antigen on the surface of its cell membrane.

(4) Another group of white blood cells, called **T-cells**, mature in the thymus gland, which is a tiny structure behind the sternum. One type of T-cell—called a **helper T-cell**—binds to and recognizes antigens presented on the surface of a macrophage. The helper T-cell then serves to co-ordinate the remaining components of the immune system to respond to the invading pathogen.

(5) The helper T-cells can be thought of as the internal army's reconnaissance unit that provides vital information to co-ordinate an attack. Once the helper T-cells have recognized an antigen on a macrophage, they send out chemical messages to other groups of white blood cells.

(6) Helper T-cells alert the **B-cells**, which mature in the bone marrow. When the B-cells receive this chemical message from helper T-cells, they begin to multiply.

(7) Some of the B-cells produce proteins called **antibodies**. The antibodies produced by the stimulated B-cells are specific for each antigen presented on the macrophage.

(8) The antibodies attach to the antigens and sometimes stick to more than one invader by creating clumps of pathogens more easily engulfed by macrophages.

(9) The antibodies act like handcuffs to immobilize and tag the invaders for easier destruction by the macrophages.

(10) Helper T-cells also send chemical messengers to stimulate **killer T-cells**. Killer T-cells regularly patrol the body looking for cells that have changed due to mutation and could become cancerous. Since viruses replicate within body cells, the killer T-cells also look for cells that have been infected with viruses. The T-cells destroy these body cells by releasing proteins that create large holes in the membranes of the target cells.

(11) During the immune response, **memory B-cells and memory T-cells** are created and remain after the invading pathogen has been destroyed. The memory cells act like military intelligence archives by keeping a blueprint of the encountered invader's antigen to make the immune response quicker the next time that particular antigen enters the body.

(12) Once the invading organisms have been destroyed, another type of T-cell called the **suppressor T-cell** ends the battle by signalling the immune system to return to its pre-infection state.

antigen: a complex molecule on the surface of an invading pathogen that triggers an immune response

It is short for antibody generator.

macrophage: a type of white blood cell that engulfs dead cells, cellular debris, and foreign cells

It presents pathogenic antigens to T-cells in the immune response.

T-cell: a type of white blood cell that matures in the thymus gland

It recognizes and destroys invaders or releases chemical messengers to co-ordinate the immune response.

helper T-cell: a type of T-cell that co-ordinates the actions of other cells involved in the immune response

It sends chemical messages to activate the antibody producing B-cells and killer T-cells.

B-cell: a type of white blood cell that produces antibody molecules when stimulated by helper T-cells

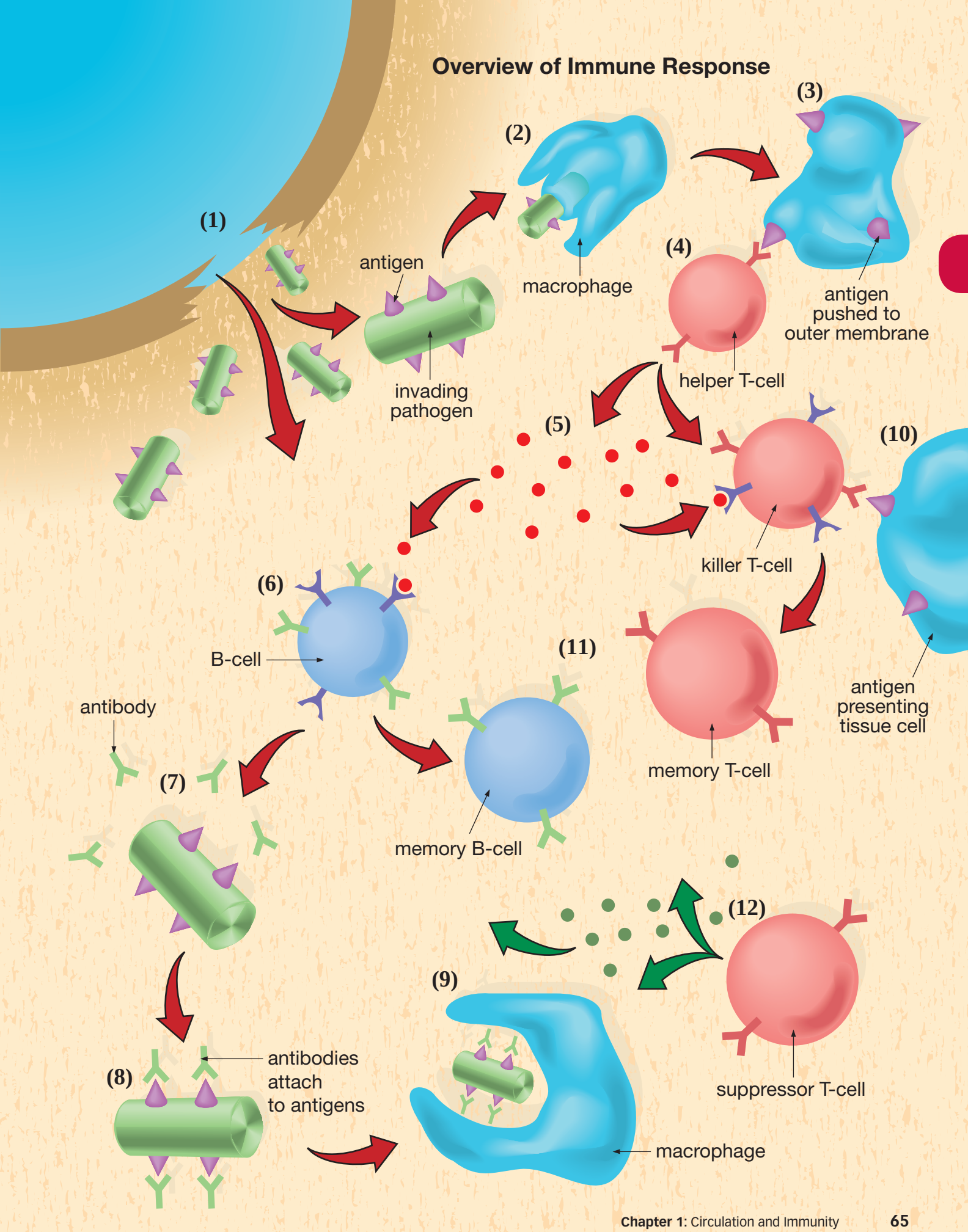
antibody: a protein molecule produced by a B-cell designed to bind to a specific antigen to facilitate its destruction

killer T-cell: a type of T-cell that recognizes and destroys body cells by releasing proteins that create large holes in the target cell's membrane

memory B-cell and memory T-cell: specialized white blood cells that persist in the bloodstream to provide future immunity to invaders bearing a specific antigen

suppressor T-cell: a type of T-cell that sends chemical messengers to stop the immune response to an antigen

Overview of Immune Response



Practice

48. Obtain a copy of the handout "Overview of Immune Response" from the Science 30 Textbook CD.

- **a.** Without looking at the labelled version of this illustration in the textbook, attempt to add the missing labels to this diagram.
- **b.** Once you have attempted 48.a., use the textbook illustration both to fill in labels that you were unable to complete and to check your work.

49. Obtain a copy of the handout "The Immune Response—Components and Roles" from the Science 30 Textbook CD.

- **a.** Without looking at information presented in the textbook, attempt to add the missing information to this table.
- **b.** Once you have attempted 49.a., use the information in the textbook both to complete and check your work.

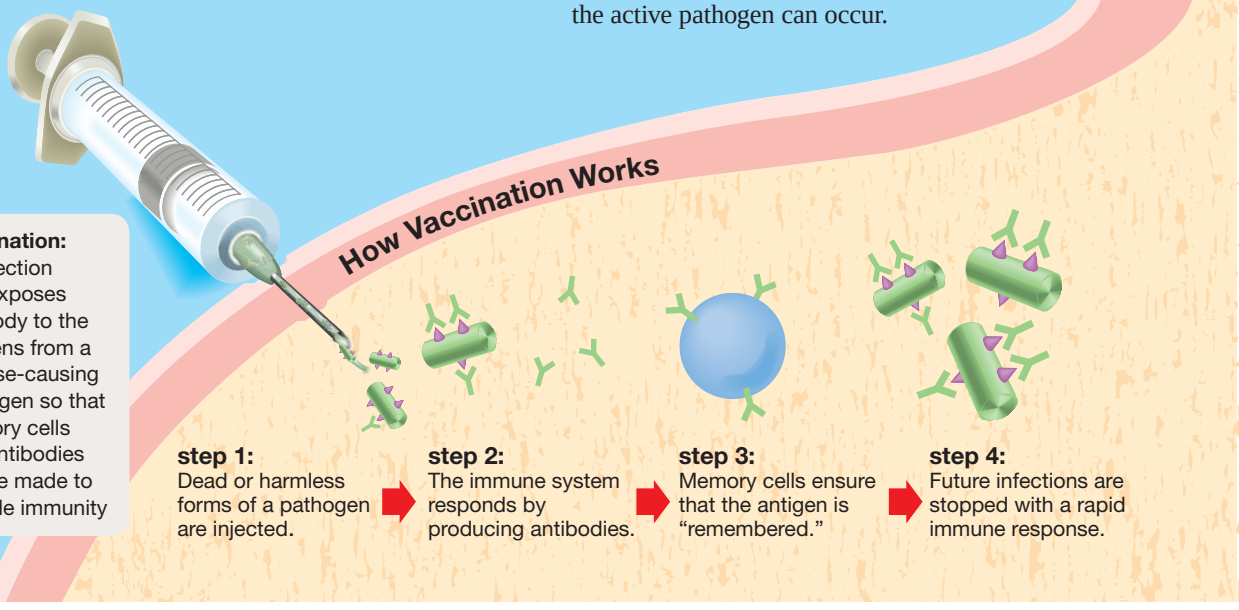
DID YOU KNOW?

The presence of antigens on organs that are transplanted from one person to another also stimulates the recipient's immune system. The organ recipient's white blood cells often recognize the antigens on the donated cells and attack them by treating the organ like a foreign invader. To prevent a rejection of transplanted organs, transplant recipients may need to take drugs that suppress their immune systems for the rest of their lives.

Vaccinations

As long as the memory T-cells for a particular antigen remain in your body, they can provide long-term immunity to the diseases you have already encountered. The reason why people usually do not get chicken pox twice is because they retain memory T-cells for the chicken-pox virus. During a second exposure to an antigen for the chicken-pox virus, memory cells become rapidly activated, divide to form clones of themselves, and quickly produce large amounts of antibodies to act against the antigen. As a result, the invading organism is usually destroyed before it can bloom into a full-blown infection.

Immunity can be artificially developed by a **vaccination**. A vaccination—also called an immunization—involves the injection of an altered or weakened form of a disease-causing pathogen or an inactivated toxin into the body. An exposure to antigens allows the body to produce memory cells and antibodies against the disease. Because the substance used in a vaccination is either a weakened form or a killed form of the disease-causing agent, the risk of becoming sick from the disease is low. Booster shots are subsequent vaccinations of some of the material to ensure that memory cells exist so a quick and intense immune response to any future exposure to the active pathogen can occur.



In Canada, most people are vaccinated when they are babies against diseases such as measles, mumps, and rubella. People travelling outside of the country may get vaccinated against diseases they would normally not be exposed to in Canada, like yellow fever. Some people choose to be vaccinated each year against strains of the flu virus.

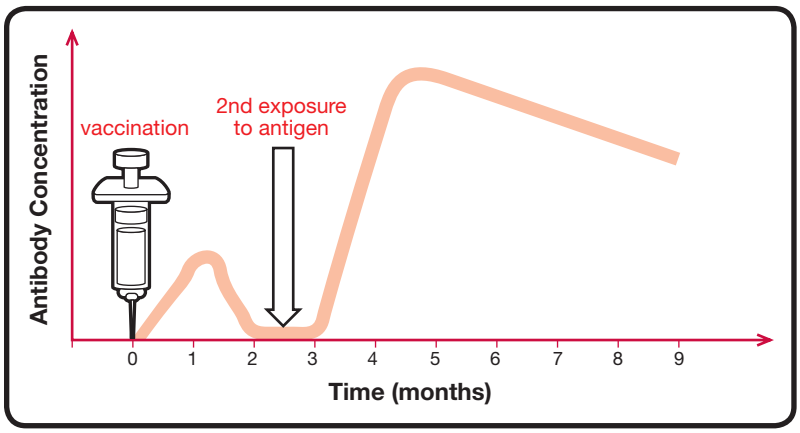


Figure A1.18: This graph shows how the concentration of antibodies is influenced by vaccination and a second exposure.

Practice

50. In your health file, list any vaccinations you have received. Alberta Health keeps a record of your vaccinations. You may need to ask a parent, a guardian, or a caregiver about vaccines you received as a baby.

Note: Some people have not received vaccinations for religious or other reasons.

Investigation

The Value of Mass Vaccinations: Weighing the Evidence

Background Information

There has recently been a debate over the benefit of administering vaccinations to masses of people within a population. Some individuals choose not to vaccinate their children or themselves. Many officials and professionals in the public health field maintain that the benefits of vaccinations still outweigh the risks.

Locate the following articles among the handouts on the Science 30 Textbook CD:

- "A Shot in the Dark"
- "Vaccine Myths and Why They Are Dangerous"

Purpose

You will consider two different opinions on the value of mass vaccinations. Then you will express your own opinion on this topic.

Procedure

step 1: Read through the "Analysis" and "Evaluation" questions to provide a focus for your reading.

step 2: Read each of the articles with the analysis questions in mind. Remember to be an active reader by using a highlighter or by taking notes as you read.

Science Skills

✓ Performing and Recording
✓ Analyzing and Interpreting

Analysis

A Shot in the Dark

1. List the negative effects of vaccination stated by interviewee Barbara Fisher.
2. State the reason Fisher gives to support a greater case for a connection between vaccinations and adverse reactions.
3. What personal experience has she had with vaccination?

Vaccine Myths and Why They Are Dangerous

4. List the negative effects of an unvaccinated population that are stated by author Dr. David Butler-Jones.
5. Describe his opinion on childhood vaccines being linked to seizure disorders, autism, and SIDS (Sudden Infant Death Syndrome).
6. What evidence does he provide to argue for a continued vaccination program?

Evaluation

7. Evaluate the two different sources for these articles. Do they seem like credible information providers?
8. Evaluate the two individuals who provide the information as either an interviewee or an author. Describe any bias or biases that they seem to present. Do you think that one individual is more credible than the other?
9. What is your stance on vaccinations? Against which diseases would you have your child vaccinated? Did your opinion change after reading the articles?

Utilizing Technology

Vaccinations for Travel

Background Information

Imagine that you have won a dream vacation! You can choose from a cruise down the Amazon River in Brazil, a visit to the famous Taj Mahal in India, an elephant ride in Thailand, or a safari tour in Kenya. Before going, you must find out what health precautions will be necessary for each of your destinations.

In this activity you will gather information from various sources of information, including the Internet, a public health centre, or a public health professional so you can answer each of the following questions.

1. List any vaccinations recommended or required before visiting one of these areas. Also, list the number of injections needed for a complete vaccination, the timeline for injections, the estimated length of immunity, and the cost, if any, for vaccination.
2. List any food or water-borne diseases to be concerned about in the location chosen, and describe precautions that will need to be taken.
3. List any vector-carried diseases—such as malaria—to be concerned about. Describe precautions that will need to be taken.

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Edward Jenner

Smallpox is a potentially deadly virus that can kill as many as one-third of the people that it infects, and it leaves those who survive it disfigured with pockmarks. Smallpox has been a scourge for thousands of years. During European colonization and exploration, the population of many Indigenous peoples was decimated by their first exposure to smallpox in places such as North America, Central America, and Australia.

In the winter of 1781–82, fur traders on the North Saskatchewan River recorded going to First Nation encampments and finding the camps full of dead bodies. An explorer named Samuel Hearne estimated that 90% of First Nations people who traded at the nearby Hudson Bay Company post died of smallpox that winter.

Scientist Edward Jenner carried out a famous smallpox experiment in 1796, which led to the development of the first vaccine. He noticed that people, such as milkmaids, who worked closely with cattle were exposed to the much less deadly cowpox disease. People who had contracted cowpox were resistant to future smallpox infections. Jenner theorized that a human exposed to cowpox may develop some kind of immunity to smallpox—he tested this theory by taking pus from a milkmaid's cowpox sore and putting it into a cut on the arm of an eight-year-old boy named James Phipps, who was the son of Jenner's gardener.

After Phipps recovered from his cowpox infection, Jenner infected him with pus from a smallpox victim; but the boy did not become sick from the disease. This was the first example of an **inoculation**. Although people often use the words *inoculation* and *vaccination* interchangeably, inoculations introduce the antigens through a cut in the skin whereas vaccinations are performed through an injection of the antigens under the skin. The injection is done by a hollow needle.

We now understand that the antigen of the cowpox virus is similar to the antigen of the smallpox virus. By exposing the boy's body to cowpox, Jenner was able to rapidly produce antibodies to the smallpox virus, which prevented Phipps from becoming sick.

Due to aggressive vaccination programs designed by the World Health Organization (WHO), smallpox had been eradicated worldwide by 1979. As a result, most countries stopped vaccinating people for smallpox in the late 1970s.

inoculation: a process of producing immunity by introducing antigens of an infectious agent through a cut in the skin's surface

Practice

51. Evaluate Edward Jenner's investigative methods. Was it ethical to use James Phipps as a test subject?

52. Explain why Indigenous populations in North America, Central America, and Australia were particularly susceptible to the smallpox virus.

53. Samples of the smallpox virus are known to exist today in only a couple of laboratories.

a. Describe some concerns associated with keeping stocks of pathogenic, disease-causing agents.

b. Describe some benefits for keeping these stocks.

Autoimmune Diseases

Figure A1.19 shows the joints of a woman's hands that are greatly swollen with rheumatoid arthritis. This disabling and painful condition is an example of an **autoimmune disease**. Sometimes a person's immune system forms antibodies against his or her body's own tissues, treating them like the antigens of invading bacteria and viruses. The white blood cells act like a rebel army attacking specific body organs or causing a variety of illnesses. In this case, the person's white blood cells are attacking the bones and cartilage in the joints of her hands. The cause of autoimmune diseases is unknown, but scientists believe that the suppressor T-cells play a role in controlling the rebelling white blood cells. Studies indicate that autoimmune diseases are more common in women than they are in men. These diseases tend to occur later in life.

You have probably heard of multiple sclerosis (MS) and diabetes mellitus (type 1 diabetes). Both are examples of autoimmune diseases. With MS, white blood cells attack parts of the nervous system. In the case of type 1 diabetes, the body mistakenly manufactures antibodies directed against the pancreas. The result is that the pancreas is unable to make insulin, which is a hormone that helps regulate the concentration of glucose in the bloodstream.

autoimmune disease: a disorder in which the immune system produces antibodies against the body's own cells

Figure A1.19: Rheumatoid arthritis can be a very debilitating disease.

1.5 Summary

The human body's internal environment is ideal for the growth of many disease-causing organisms, so the body must have defenses to protect itself from disease. The skin, cilia, and secretions—such as stomach acid, tears, and mucus—act as the first line of defence against potential invading organisms. White blood cells act as a defending army to identify and destroy any disease-causing organisms that make it through the skin and secretion barrier.

Disease-causing organisms can be passed on in several ways. These include being spread through droplets in the air, by eating or drinking contaminated food or water, via cuts in the skin, or through vectors such as mosquitoes. Disease-causing organisms, including protozoans, fungi, bacteria, and viruses, all have distinctive antigens on their surfaces that allow the white blood cells to recognize them as foreign invaders.

The white blood cells of the immune system are specialized for specific functions. Macrophages ingest disease-causing organisms displaying antigens from the destroyed invader. Helper T-cells recognize antigens and co-ordinate the attack against the invaders. B-cells produce antibodies that bind to the disease-causing organism's antigens. Killer T-cells destroy virus-infected body cells. Suppressor T-cells end the immune response. Memory T-cells and memory B-cells remain to provide a faster response to subsequent encounters with the antigen.

Vaccinations are a way of artificially exposing someone to an antigen of a disease-causing organism so that the body can produce memory cells and antibodies to create a greater immunity to exposure from the antigen.

1.5 Questions

Knowledge

1. Explain how each of the following disease-causing organisms overcomes the body's natural defenses to enter the body.
   - **a.** malaria
   - **b.** hepatitis C
   - **c.** tuberculosis
   - **d.** salmonella
2. Explain how an autoimmune disease differs from an infectious disease.
3. Create a table comparing the similarities and differences between bacteria and viruses.
4. Locate the applet "Battles in the Bloodstream" on the Science 30 Textbook CD. Watch the applet to confirm your understanding of how the immune system responds to a microscopic pathogen. Turn the sound off. Then watch the applet again. As you watch it, supply a new audiotrack by providing a description of what is occurring. Be sure to include the following key words in your spoken commentary: macrophage, antigens, helper T-cells, B-cells, antibodies, killer T-cells, suppressor T-cells, memory B-cells, and memory T-cells.

Applying Concepts

5. Explain how the following problems impair the body's ability to fight against disease-causing organisms.
   - **a.** A person with hemophilia has blood that does not clot properly.
   - **b.** The skin is badly damaged so that tissues are exposed.
   - **c.** Someone who has HIV has many helper T-cells destroyed by the virus.
6. Explain how the following methods can be used to assist the body's ability to fight against disease-causing organisms.
   - **a.** vaccinations given at birth
   - **b.** antibiotics prescribed when you have an infection
   - **c.** antiseptics used during operations
7. In a group, act out for the class the body's immune response to an invading bacteria or virus. Each group member will be assigned the role of one immune response component (disease-causing organism, macrophage, helper T-cell, B-cell, killer T-cell, suppressor T-cell, or the memory T-cell). Small groups may need to have members perform the role of more than one component. Before performing for the class, your group may want to spend some time developing a script, finding costumes for different roles, and rehearsing.

Chapter 1 Summary

In this chapter you have examined the structure and function of the circulatory system. You have seen how the heart functions to pump blood through the body, how the vessels of the circulatory system are specialized to carry blood around the body, and how blood functions as a medium to transport substances and to protect against disease-causing pathogens. You have also seen how problems that affect the circulatory system impair its functioning, and you have examined some of the technologies used to treat these problems.

Most diseases that make us feel sick are caused by lifestyle choices or by the invasion of disease-causing organisms. In your health file, you have examined and recorded information about your health and risk factors. In Chapter 2 you will look at the mechanisms of inheritance and learn how certain diseases can arise from inherited traits rather than from the environment. You will also examine the ethics of using genetic technologies.

Summarize Your Learning

In this chapter you have learned a number of new biological terms, processes, and theories. It will be much easier for you to recall and apply the information you have learned if you organize it into patterns.

Since the patterns have to be meaningful to you, there are some options about how you can create this summary. Each of the following options is described in "Summarize Your Learning Activities" in the Reference section. Choose one of these options to create a summary of the key concepts and important terms in Chapter 1.

Option 1: Draw a concept map or a web diagram.	Option 2: Create a point-form summary.	Option 3: Write a story using key terms and concepts.	Option 4: Create a colourful poster.	Option 5: Build a model.	Option 6: Write a script for a skit (a mock news report).

Chapter 1 Review Questions

Knowledge

1. List the four main functions of the human circulatory system.
2. Copy and complete the following table comparing the chambers of the mammalian heart.

Heart Chamber	Location	Type of Blood Found in Chamber	Function
right atrium	top right	deoxygenated	receives blood from body from vena cava
right ventricle			
left atrium			
left ventricle			

3. Describe three ways in which arteries and veins differ.
4. List the four main components of blood. Rank these components by their relative proportion in a blood sample from the largest proportion to the smallest proportion.
5. State which of the four major blood components is responsible for initiating the clotting process.
6. Define *cardiovascular disease*.
7. Distinguish between a heart attack and a stroke.
8. List four ways by which disease-causing pathogens can enter the body.
9. Define *vaccination*.
10. Obtain a printed copy of the handout titled "Overview of Immune Response" from the Science 30 Textbook CD.
    a. Use a pair of scissors to cut out all 13 images.
    b. Without looking at the textbook, place these images in the correct sequence.
    c. Check your answer to question 10.b. with the information presented in this chapter. Make the necessary adjustments or corrections and then use a glue stick or transparent tape to attach the images to a piece of paper in the correct sequence.

Applying Concepts

11. From the following data, carefully examine the relationship between the heart rate and the mass of an organism.

RESTING HEART RATE VERSUS MASS

Organism	Mass (g)	Resting Heart Rate (beats/min)
mouse	25	670
rat	200	420
guinea pig	300	300
rabbit	2000	205
small dog	5000	120
large dog	30 000	85
human	70 000	72
horse	450 000	38
African elephant	6 000 000	30

a. Observe trends from this data. Write a statement that describes how heart rate is affected by the size of an organism.

b. Estimate the heart rate of a 3-kg cat from these data patterns.

c. *Tyrannosaurus rex* was a ferocious carnivore that lived from about 85 to 65 million years ago. Paleontologists estimate that T.rex had a mass of up to 7000 kg. Estimate the resting heart rate of T.rex by extending the trends in this data.

d. The extinct dinosaur *Apatosaurus* (also called *Brontosaurus*) belonged to the long-necked family of sauropods. This family included the largest land animals to ever live. Estimate the heart rate of *Apatosaurus*, which had a mass of 27 metric tons (27 000 kg) by extending the trends in this data.

e. What problem does extending the trends in the data pose for paleontologists who are studying the circulatory systems of large extinct dinosaurs?

Use the following information to answer questions 12 to 14.

In Lesson 1.1 you learned how the parts of the heart work together as a system. A great way to consolidate all that you have learned about the heart is to build a three-dimensional model of this amazing pump.

To build the model, you will need the following:

- modelling materials such as Femo, Plasticine, or playdough
- a piece of stiff cardboard to act as a base for the model
- a copy of the handout titled "The Human Heart—Labelled" from the Science 30 Textbook CD

Note: You can make your own playdough by using one of the recipes on the "Playdough Recipes" handout on the Science 30 Textbook CD.

Design Criteria for the Heart Model

These models are designed to be three-dimensional representations of the handout titled "The Human Heart—Labelled." All the key structures on the heart diagram are to be included in your model. Even though the model will not include labels, if someone points to a heart structure on your model, you should be able to answer the following focusing questions:

- What is the name of this structure?
- Where would blood in this part of the heart go next?
- Does this part contain oxygen-rich blood or oxygen-poor blood?

12. Build your three-dimensional model of the heart according to the design criteria. Make sure all the parts connect so that if the parts were hollow, blood could flow through the heart. Building the model on a piece of stiff cardboard will make it easier to clean up and to move the finished product.

13. When your model is complete, show your work to other students. Ask the other students their opinions about what are the most effective aspects of your model as well as how it could be improved. Provide similar feedback to other students who completed this activity.

14. Use the feedback you received from your classmates as well as what you observed in the other models to answer the following questions.

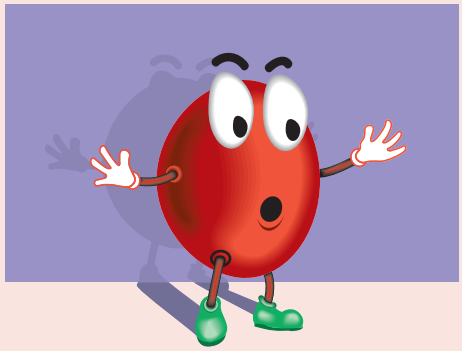
a. What are the strong points of your model?

b. How could your model be improved?

Use the following information to answer question 15.

You have been asked to volunteer to help children in elementary school learn about the circulatory system. Your task is to create a comic strip to accompany the following description in an elementary school resource.

Robbie the Red Blood Cell is in the vena cavae on his way back from the brain where he just delivered some fresh oxygen to a brain cell and grabbed some waste carbon dioxide. While in the brain, Robbie found out that his friend Tina Toe Cell is in desperate need of oxygen.



15. Create a colourful and attractive comic strip with a series of six to eight sequential panels that explain what happens to Robbie as he moves through the circulatory system from the vena cavae to the toe and back again. You should aim to design a comic strip that could teach about the pathway of blood in the human body to someone who has never studied the circulatory system.

16. The bodies of athletes who compete in endurance events—such as marathon runs, cross-country skiing, or bike races—require a huge amount of oxygen during the competition. Some endurance athletes have tried to improve their performance by removing their own blood, centrifuging it to isolate the red blood cells, storing it while the body replaces the lost blood, and then injecting it back into their own body right before the race. This process of "blood doping" has been banned by the International Cyclist Union (UCI) and also by the International Olympic Committee (IOC).

a. Why would injecting more red blood cells into their bodies create an advantage for athletes?

b. Explain why it is more difficult to prove that athletes are using blood doping rather than taking performance-enhancing drugs.

c. Predict the effects of blood doping on the athlete's blood pressure.

d. List some possible negative health effects of the practice of blood doping.

e. Athletes often train at high altitudes before a competition. The thin air at these altitudes stimulates red blood cell production. Some athletes feel that the practice of blood doping before a competition is no different than training at high altitudes. Evaluate this specific argument.

17. Design an Experiment

A new over-the-counter weight-loss drug has just been released onto the market. Most users of the product are reporting fantastic weight-loss results. However, some clients are reporting an increase in their heart rates as a side effect. The drug company claims that there is no connection between these reported heart effects and the proper use of their product. A regular user of the product recently died of a heart attack. There is now public concern about the drug's use.

Your job is to design an experiment that safely tests whether there is a correlation between using the drug and risking an increased or irregular heartbeat that could result in a heart attack. A correlation is an assessment of how strongly two variables are related. If one variable changes and the other variable changes with it, there is said to be a correlation.

Provide a description of an investigation you would carry out, what materials you would use, and how you would ensure that the experiment was done safely. Your experimental design should clearly identify the manipulated and responding variables as well as listing at least three controlled variables. It should also take into account ethical and safety considerations.

18. Whales and seals are mammals well adapted for diving. For example, the Weddell seal is able to remain underwater for over an hour without surfacing to breathe. List some possible adaptations of a diving mammal's circulatory system that would allow it to remain below the water for so long.

19. A doctor looks at three patient files containing information from lab tests and lifestyle data. Note that μL is a microlitre.

Health File Information	Patient 1	Patient 2	Patient 3
Cholesterol Level	200 mg/dL	280 mg/dL	150 mg/dL
Activity Level	moderate regular weekly exercise	little or no weekly exercise	intense physical training
Resting Heart Rate	72 beats per minute	81 beats per minute	50 beats per minute
Smoker?	occasionally	yes	no
Blood Pressure	120/80 mmHg	147/95 mmHg	120/80 mmHg
White Blood Cell Count	14 000 per μL	6500 per μL	5000 per μL

a. Explain which patient the doctor would be most concerned about in terms of circulatory health? What lifestyle changes or future precautions might the doctor recommend to the high-risk patient?

b. Which patient most likely has an infection?

c. State the likely reason why the resting heart rate of Patient 3 is significantly lower than the other two patients.

Use the following information to answer questions 20 to 24.

Investigating Primary Literature: Predicting Sudden Death

Cardiovascular disease is the number one cause of death in Canada, with nearly 80 000 annual victims. For almost half of these people, death occurs within minutes of the first symptoms of a heart attack. In many cases the first heart attack pains were the first indication that this person had poor cardiovascular health—but by then it was too late! Clearly, if there is a way to predict whether an apparently healthy person is at risk of sudden death from a heart attack, preventative measures can be taken and lives can be saved.

Researchers from France and Italy analyzed data over 23 years from men working around Paris in the French civil service. The researchers claim that they have found a practical way to predict which members of a healthy population of men, who have no previous history of cardiovascular disease, may be susceptible to sudden death from heart attack.

This research is described in the article "Heart-Rate Profile During Exercise as a Predictor of Sudden Death." This article is found as a handout on the Science 30 Textbook CD. Since this article was published in the *New England Journal of Medicine*, it can be a challenging piece to read because it was written for physicians and medical science researchers. Nevertheless, there is value in reading primary literature because you can learn about scientific discoveries as they are reported by those people who actually did the research.

20. Obtain a copy of the handout "Heart-Rate Profile During Exercise as a Predictor of Sudden Death" from the Science 30 Textbook CD.

- **a.** Read questions 21 to 24 to develop a sense of what to focus upon when you read the article.
- **b.** Carefully read the article with these questions in mind. Remember to be an active reader by using a highlighter pen and/or by taking point-form notes. You can learn more about effective reading strategies by turning to "Reading for Understanding" in the Reference section.
- **c.** Save this evidence of your active reading strategies to help you answer questions 21 to 24.

21. The researchers used three tests to predict whether one of the men being studied was at risk of sudden death from a heart attack.

- **a.** Identify and describe each of the tests.
- **b.** Identify the test that appears to have the best ability to predict sudden death from a heart attack.

22. Describe screening procedures used to choose subjects for the study. Explain why these procedures were necessary.

23. The data was collected from 5713 men in the study.

- **a.** How many men were in the control group, and how was this group defined?
- **b.** How many men in the group died sudden deaths from heart attacks?

24. List some limitations of this research.